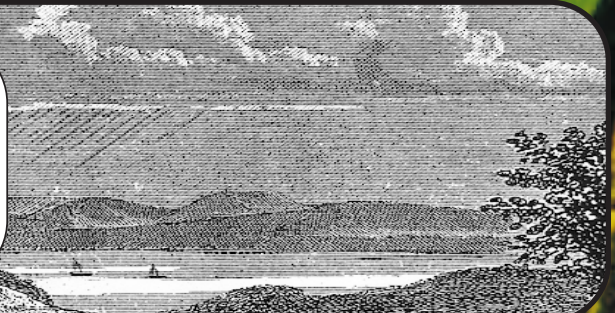


**HABITAT QUALITY AND
BIOLOGICAL INTEGRITY
ASSESSMENT
WESTERN BRANCH
PATUXENT RIVER
FEASIBILITY STUDY**



**CHESAPEAKE BAY AND
WATERSHED PROGRAMS**
MONITORING AND
NON-TIDAL ASSESSMENT
CBWP-MANTA- EA-01-4





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Final Data Report:

Habitat Quality and Biological Integrity Assessment

Western Branch Patuxent River Feasibility Study

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Monitoring and Non-Tidal Assessment Division**

Annapolis, MD

Introduction

This work was conducted by the Maryland Department of Natural Resources under contract No. DACW 31-99-P-0048. The goal of the project was to assess the physical habitat qualities and biological resources of four stream sites within the Western Branch of the Patuxent River watershed. The study was requested by the US Army Corps of Engineers, Baltimore District, to assist in determining stream improvement potential and to prioritize resources for proposed restoration activities at the four sites. Restoration would involve modifying existing concrete channels to increase water depth and to allow sediment accumulation. The restoration of the riparian areas is also proposed.

The data presented in this report were used to compare existing physical and biological features among the sites, and to assess the potential for biological improvements, including the passage of resident fishes through the channels. Improvements to the streams following restoration would be expected to vary among the four channels depending on the physical, chemical, and land use factors affecting each site.

Methods

Four stream sites currently under consideration for stream restoration by the Corps of Engineers were sampled to characterize ecological conditions between October 1998 and March 1999. Each site was divided into three 75 meter segments for sampling. One segment was located within the concrete channel to be modified, and the remaining segments were located upstream and downstream of the concrete channel. The four site locations and the segments within each site are shown in Figures 1 and 2.

Data were collected using Maryland Biological Stream Survey (MBSS) methods described by Kazyak, 1997. MBSS data collection methods can be classified into three general categories: biological, chemical, and physical habitat.

Biological Collections

Fish community data were collected in October 1998 in accordance with the MBSS summer index period (June-September). Fish community sampling was conducted using 12 volt direct current backpack electrofishing units. Each 75 meter segment was sampled using a two pass reduction method. Block nets were placed at each end of the segment, and all available habitats were thoroughly sampled. For each replicate pass, all captured fish were identified to species, enumerated, weighed in aggregate, and released.

Benthic macroinvertebrates were collected in March 1999 to meet spring index period requirements established by the MBSS. Benthos are ideally sampled during spring, when they are reliable indicators of environmental stress (Plafkin et al., 1989). Benthos were collected with a D-net from the best available habitats, including riffles, root wads, woody debris, leaf packs, macrophytes, and undercut banks. Benthos were preserved in 70% alcohol and identified to genus (if possible) in the laboratory.

Water Chemistry

Water chemistry samples were collected in March 1999, in accordance with MBSS standards. Water samples were analyzed for chloride, phosphate, total orthophosphate, nitrate nitrogen, nitrite nitrogen, total nitrogen, total organic carbon (TOC), ammonia, pH, acid neutralizing capacity (ANC), sulfate, dissolved organic carbon (DOC), and conductivity. Water temperature and dissolved oxygen

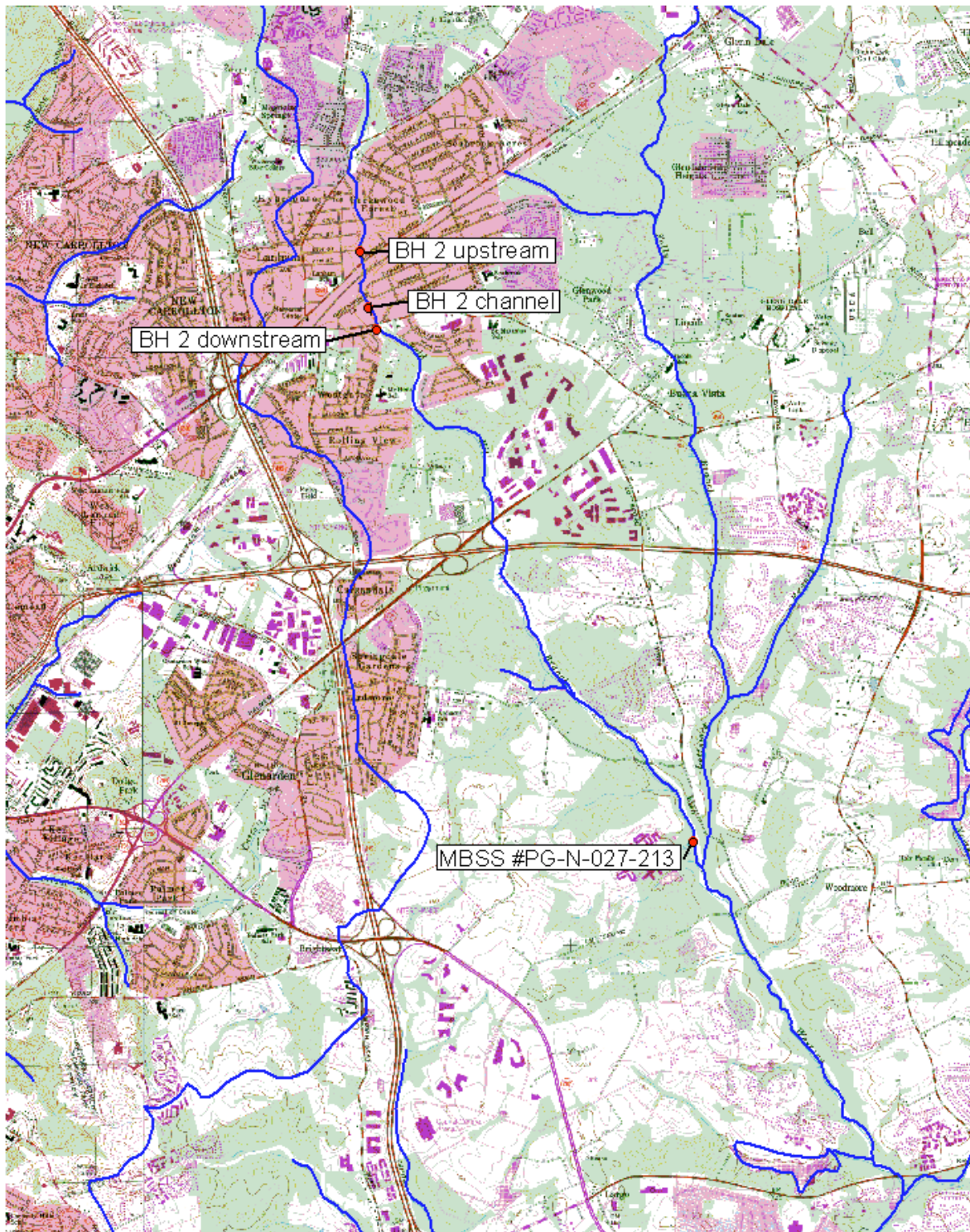


Figure 1: Bald Hill Branch Sites.

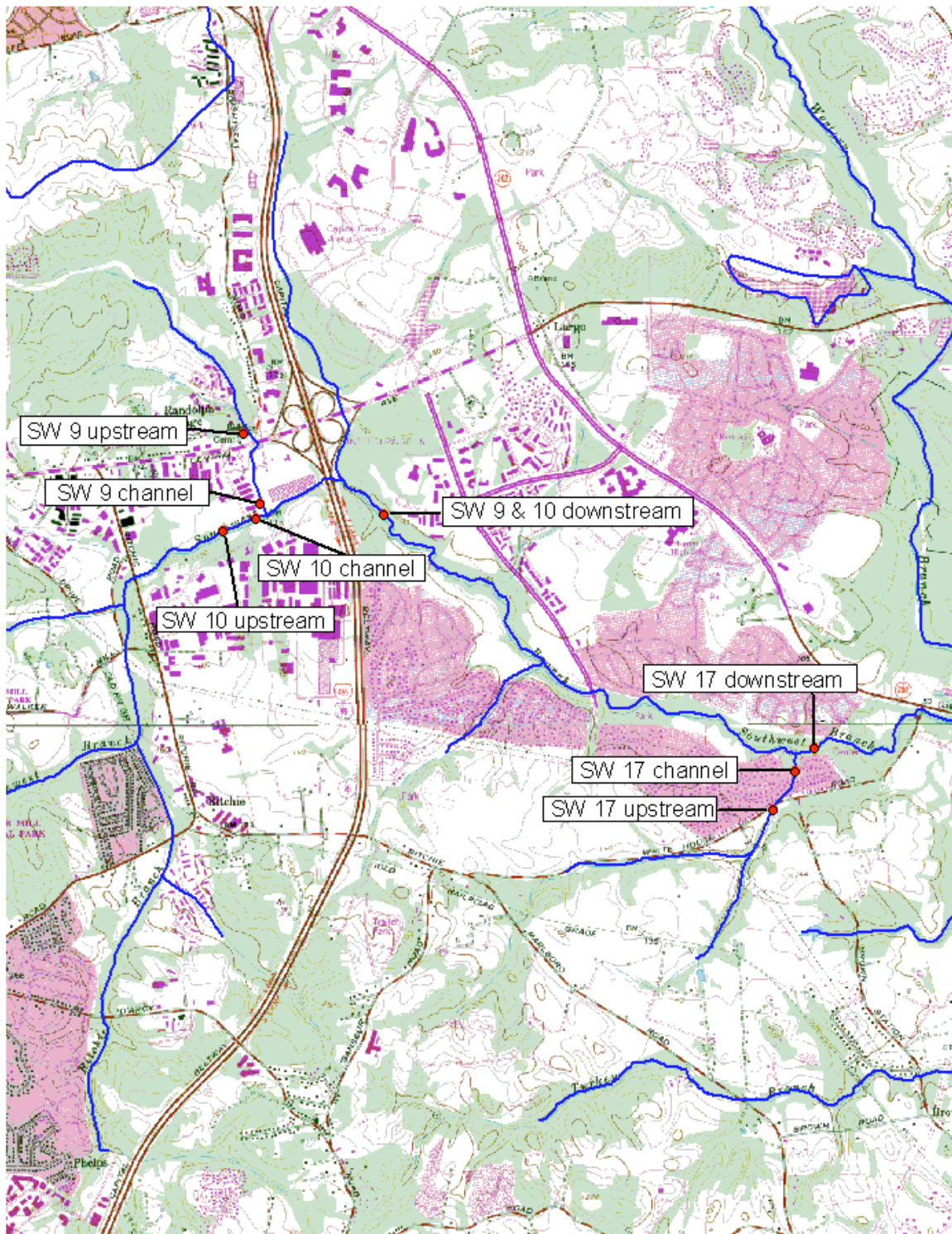


Figure 2: Southwest Branch Sites.

were measured during summer sampling, when high temperatures and relatively low flows cause dissolved oxygen to be at its lowest.

Physical Habitat

Physical habitat assessments were conducted to evaluate habitat effects on biota. MBSS habitat assessment procedures were derived from two methods: EPA's Rapid Bioassessment Protocols (Plafkin et al. 1989), as modified by Barbour and Stribling (1991), and Ohio EPA's Qualitative Habitat Evaluation Index (Ohio EPA 1987). Several qualitative parameters (instream habitat, epifaunal substrate, velocity/depth diversity, pool/glide/eddy quality, riffle quality, channel alteration, bank stability, embeddedness, channel flow status, and shading) were scored based on visual observations. Minimum riparian buffer width (up to 50 m from the stream) and vegetation type in the buffer were recorded, as well as scores for aesthetic value and site remoteness. Quantitative measurements at each site included the number of woody debris and root wads, maximum depth, stream gradient, wetted width, depth, and discharge.

Quality Control

Quality control and quality assurance procedures for this project followed the MBSS QA/QC methods as outlined in the Maryland Biological Stream Survey Sampling Manual (Kazyak, 1997).

Results and Discussion

Bald Hill Branch, Site 2

Water Chemistry

Based on laboratory pH and ANC data, no adverse acid conditions exist at the Bald Hill Branch site. Field measurements of pH indicated that while the upstream and downstream segments had neutral or nearly neutral (7.60) pH, the channel segment was slightly alkaline, at 8.37. DOC was moderately high (7.45 mg/L), but is thought to reflect natural wetland conditions and not anthropogenic effect. This assessment is supported by a high concentration of TOC (6.9 mg/L), which usually results from the presence of organic material, such as leaves, in slow moving streams and wetlands. Nitrate and phosphate levels were also within those expected under natural conditions. Sulfates, however, were moderately high at 30 mg/L, and are possibly the result of urban runoff.

The concentration of dissolved oxygen surpassed the state water quality criterion of 5 mg/L by a slim margin (5.2 mg/L) at the upstream segment, and by a greater extent (6.8 mg/L) at the downstream segment. However, there was an extremely high level of dissolved oxygen in the channel (14.7 mg/L), which resulted from the fact that the water depth in the channel was very low, allowing for easy aeration. Additionally, it is likely that the algae lining the channel contributed to the elevated dissolved oxygen measurement. However, this contribution was probably small relative to the amount of oxygen that was introduced by physical means. Overall, chemistry samples indicated that water quality was not a limiting factor for aquatic biota in Bald Hill Branch.

Physical Habitat

Habitat assessment scores indicated that the habitat in Bald Hill Branch Site 2 is generally degraded. The channel segment was rated Poor for many parameters, such as instream habitat, epifaunal substrate, and channel alteration. However, the upstream and downstream segments scored below the optimal range for several habitat parameters, with both scoring Poor for velocity/depth diversity and riffle/run quality.

Several detrimental effects of channelization were apparent at the Bald Hill Branch channel segment. The widening of a stream which typically occurs with channelization causes the stream

to contain less than an ideal amount of water, and thereby limits habitat for aquatic life. In this case, the channel segment was full to only 60% capacity, whereas the upstream and downstream segments were full to 70% and 95%, respectively. Furthermore, the channel segment was devoid of riparian vegetation, which is needed for the protection of streamwater against runoff from impervious surfaces. The downstream and upstream segments, in contrast, had at least 12 to 16 meters of riparian vegetation. While all three Bald Hill Branch segments were found to contain human refuse and be in close proximity to roadside access, the channel segment scored the lowest of the three for aesthetic value and segment remoteness.

Fish IBI Evaluation

The Fish Index of Biotic Integrity (IBI), as developed by the Maryland Department of Natural Resources (Roth et al., 1998), was calculated for each of the three Bald Hill Branch segments. Although the downstream segment was rated Poor (2.75), and the upstream segment rated Very Poor (1.75), the channel segment received the lowest score (1.50) and was also rated Very Poor. At all three segments, the low scores generally resulted from the fact that all species collected were considered pollution-tolerant and were generalists, meaning that they could take advantage of many different food types. The particularly low score at the channel segment was caused by a lack of species diversity; only one species, the mummichog (*Fundulus heteroclitus*), was collected at this segment, although it was found in relatively high numbers.

The low IBI scores at Bald Hill Branch are possibly the result of human activity; however, because this system is moderately influenced by naturally occurring tannic acid, species diversity is expected to be somewhat low in response to natural conditions.

Predicted and Observed Fishes

To understand how fish populations might have changed as a result of stream channelization, an analysis was performed in which habitat and water quality parameters known to affect fish species' distributions were used to make predictions about what species of fish would be present at the channel segments. If optimal conditions for a given species existed, then that species was expected to occur at the segment. The parameters used to make the predictions were factors that are not typically human-influenced, such as watershed area, DOC, etc. When species that were expected

to occur did not appear in our samples, other habitat and water quality parameters were examined in order to explain species' absences. Among these were factors that could be easily altered by human activities, such as channel alteration and sulfate and nitrate concentrations.

For the Bald Hill Branch channel segment, 14 species of fishes were expected, none of which were found. Mummichog had not been predicted because it is typically restricted to estuarine or highly degraded lotic systems. Predicted species and the habitat factors that are potentially limiting their distributions are shown in Table 1. Lack of depth was a factor that explained absence for all species; since the channel had a maximum depth of only 8 cm, there was simply not enough water volume to support most species. In addition, poor instream habitat, low velocity/depth diversity, and a high degree of channel alteration also contributed to the absence of many species. These habitat features would need to be improved in order to restore these species to the channel segment.

Table 1: Expected species and potentially limiting habitat factors for Bald Hill Branch Site 2.

Species	Depth	Instream Habitat	Epifaunal Substrate	Velocity/ Depth	Pool Quality	Channel Alteration	Percent Impervious Surfaces
Blacknose dace	x						
Eastern mudminnow	x						
Tessellated darter	x	x				x	
Pumpkinseed	x	x			x	x	
White sucker	x	x		x	x	x	
Pirate perch	x						x
American eel	x	x				x	
Redbreast sunfish	x	x		x	x	x	
Golden shiner	x	x				x	
Creek chubsucker	x	x				x	x
Redfin pickerel	x	x				x	x
Tadpole madtom	x	x		x	x	x	x
Chain pickerel	x	x	x	x	x	x	x
Bluespotted sunfish	x						x

Barriers to Migration

To assess whether the concrete channel was acting as a barrier against the upstream/downstream movement of fishes, the composition of species collected upstream and downstream of the channel were compared. In Bald Hill Branch, only four species of fish were found upstream of the channel: mummichog (*Fundulus heteroclitus*), golden shiner (*Notemigonus crysoleucas*), goldfish (*Carassius auratus*), and blacknose dace (*Rhinichthys atratulus*). While all four species were also found at the downstream segment, six additional species were found at the downstream segment that were not found upstream. These include the swallowtail shiner (*Notropis procne*), bluespotted sunfish (*Enneacanthus gloriosus*), redbreast sunfish (*Lepomis auritus*), creek chubsucker (*Erimyzon oblongus*), eastern mudminnow (*Umbra pygmaea*), and pumpkinseed (*Lepomis gibbosus*). It is therefore likely that the channel is acting as a barrier against the upstream movement of some fish species.

Benthic IBI Evaluation

The Benthic Index of Biotic Integrity (IBI), also developed by the Maryland Department of Natural Resources (Stribling et al., 1998) was calculated for each of the Bald Hill Branch segments. While both the upstream and downstream segments were rated Poor at 2.43, the channel segment received the lowest score (1.86), and was rated Very Poor. The low scores generally resulted from the absence of EPT (pollution-sensitive) taxa, as well as the lack of specialized taxa such as scrapers and clingers. However, the system appears to be moderately influenced by naturally occurring tannic acid, so even under natural conditions, relatively low diversity would be expected.

Distribution of Herpetofauna

Differences were seen in the distribution of herpetofauna among the three Bald Hill Branch segments, although overall species diversity was low. Upstream from the channel, both the green frog (*Rana clamitans melanota*) and the bullfrog (*Rana catesbeiana*) were found. In contrast, only the green frog was found downstream, and no herpetofauna were found in the channel, which lacked the habitat structure and slow water necessary for frogs and other amphibians.

Bald Hill Branch, MBSS Study

In addition to data collected in Bald Hill Branch for the Corps of Engineers, data were also collected from a separate site in Bald Hill Branch as part of the Maryland Biological Stream Survey (MBSS) during 1997. Although it was located downstream from the cement channel, the MBSS site was considered well-removed from any possible channel effects.

Results reflected the wetland nature of Bald Hill Branch. The site had moderate DOC levels (6.60 mg/L) in combination with Good pool quality and Poor riffle quality. Other habitat and water quality parameters indicated that there was Good aquatic habitat, with neutral pH, high dissolved oxygen (9.3 mg/L), high shading (97%), and adequate riparian vegetation. A high diversity of fishes and benthic macroinvertebrates supported this assessment, resulting in fish and benthic IBI scores of 4.5 (Good) and 3.6 (Fair), respectively. Additionally, the site supports stripeback darter (*Percina notogramma*), and glassy darter (*Etheostoma vitreum*), both listed as endangered in the state of Maryland by the Maryland Heritage and Biodiversity Conservation Programs, and chain pickerel, an important gamefish.

Southwest Branch of Western Branch, Site 9

Water Chemistry

Laboratory analysis showed that Southwest Branch Site 9 is not acidified, having neutral pH and a reasonable ANC reading. Like Bald Hill Branch, however, field measurements of pH indicated that the channel was slightly alkaline, at 8.06, whereas the upstream and downstream locations had neutral or nearly neutral (7.48) pH. Measurements of DOC and nitrate-nitrogen fell within natural levels, but sulfates were somewhat high (26.5 mg/L), possibly as a result of urban runoff.

Water temperature measured in the field was 3° C higher in the channel than upstream, which is not surprising given that the channel was estimated to be 2% shaded, whereas the upstream segment was approximately 90% shaded. Like Bald Hill Branch, dissolved oxygen was highest in the channel (11.8 mg/L), where the maximum water depth was only 6 cm and the water was moving quickly due to the channel's relatively steep gradient (1.20%). The bottom at the channel segment was also observed to be covered by algae, which could contribute to high dissolved oxygen levels

during the day. Dissolved oxygen at the upstream and downstream segments was well above the state criterion of 5 mg/L, with 7.9 and 6.6 mg/L, respectively.

Physical Habitat

At Southwest Branch Site 9, the channel segment received significantly lower scores than the upstream and downstream segments for many habitat parameters. The channel segment was severely lacking in suitable instream habitat, epifaunal substrate, and velocity/depth diversity. Furthermore, it received the lowest possible score (=0) for pool/glide/eddy quality, riffle/run quality, and channel alteration. While the upstream and downstream segments were rated Sub-optimal in terms of velocity/depth diversity, both were rated Optimal for pool/glide/eddy quality. The upstream segment was also observed to have Optimal instream habitat.

Other habitat parameters also indicated that the channel segment is in poor condition. For example, riparian vegetation shaded about 90% of the upstream and downstream sample segments, whereas the channel segment had no riparian vegetation and was only 2% shaded. Because of artificial widening, the channel was filled to just 45% capacity, compared to the 85% and 75% capacity of the upstream and downstream segments, respectively. Additionally, the channel was devoid of rootwads and woody debris, which provide crucial habitat for benthic macroinvertebrates.

Fish IBI Evaluation

Fish IBI scores for Southwest Branch Site 9 show a large discrepancy between the channel and non-channel segments, with the upstream and downstream segments each rated as Good at 4.00, and the channel segment receiving the lowest possible score of 1.00, a Very Poor rating. The channel segment was entirely devoid of fishes, whereas the upstream and downstream segments showed good species diversity. At these segments, there was a low percentage of pollution-tolerant species, a high percentage of lithophilic spawners (those fish requiring rock substrates for spawning), and a high number of individuals per square meter. Hence, the IBI scores reflected both the high diversity and high density of fishes upstream and downstream from the channel.

Predicted and Observed Fishes

Fourteen species of fish were expected to occur at the Southwest Branch Site 9 channel

segment, but no fish were collected. Predicted species and the habitat factors that are potentially limiting fish distributions are shown in Table 2. Low water depth contributed to the absence of all species. Maximum water depth in the channel was only 6 cm, leaving little habitable space. Additional reasons for species' absences were poor instream habitat, poor velocity/depth diversity, poor pool quality, and a high degree of channel alteration. These characteristics, as well as water depth, would need to be improved in order to restore many species to the channel.

Table 2: Expected species and potentially limiting habitat factors for Southwest Branch Site 9.

Species	Depth	Instream Habitat	Epifaunal Substrate	Velocity/ Depth	Pool Quality	Channel Alteration	Percent Impervious Surfaces
Creek chub	x			x	x	x	
Blacknose dace	x			x		x	
Eastern mudminnow	x				x		
Tessellated darter	x	x		x	x	x	
Rosyside dace	x	x		x	x	x	x
Pumpkinseed	x	x			x	x	
White Sucker	x	x		x	x	x	
Least brook lamprey	x	x		x	x	x	x
Pirate perch	x				x		x
American eel	x	x		x	x	x	
Sea lamprey	x	x	x	x	x	x	x
Creek chubsucker	x	x			x	x	x
Common shiner	x	x		x	x	x	x
Chain pickerel	x	x	x	x	x	x	x

Barriers to Migration

The upstream and downstream portions of Southwest Branch Site 9 had 13 species of fish in common. Only one individual of one species, a juvenile largemouth bass (*Micropterus*

salmoides), was found upstream from the channel but not downstream. However, there were six species found downstream that were not found upstream: eastern mudminnow (*Umbra pygmaea*), bluegill (*Lepomis macrochirus*), satinfish shiner (*Cyprinella analostana*), golden shiner (*Notemigonus crysoleucas*), creek chub (*Semotilus atromaculatus*), and yellow bullhead (*Ameiurus natalis*). Consequently, some fish species may not travel upstream of the cement channel, even though adequate habitat and water quality conditions occur for these species. The catadromous American eel (*Anguilla rostrata*) was found upstream and downstream of the channel.

Benthic IBI Evaluation

Unlike the trend shown by the fish IBI scores, the benthic IBI scores did not show a large discrepancy between the channel and non-channel segments. The benthic IBI rated the upstream and channel segments Poor (2.71 and 2.14, respectively), and the downstream segment Very Poor (1.30). The downstream segment scored particularly low because it consisted primarily of pool habitat, and did not contain sufficient riffle area needed by many macroinvertebrates. At all segments, there were low total numbers of organisms, as well as low diversity. Additionally, the absence of pollution sensitive taxa, such as Ephemeroptera (mayflies) and Plecoptera (stoneflies), together with the presence of very pollution tolerant taxa, such as tubificid worms and chironomids (midges), contributed to the poor IBI scores.

Distribution of Herpetofauna

Herpetofauna were found upstream and downstream of the channel at Southwest Branch Site 9, but not in or along the channel, which lacked suitable habitat. Upstream from the channel, two species were found: the green frog (*Rana clamitans melanota*) and the pickerel frog (*Rana palustris*). Downstream, green and pickerel frogs were found as well as the eastern box turtle (*Terrapene c. carolina*).

Southwest Branch of Western Branch, Site 10

Water Chemistry

Southwest Branch Site 10 was found to have a neutral pH and high ANC (2323 µeq/L), which may be related to urban runoff. Field measurements of pH showed only minor differences

among the upstream, channel, and downstream segments. DOC and nitrate-nitrogen were within reasonable levels, but sulfates were somewhat high at 42 mg/L, possibly resulting from urban runoff.

Water temperature was just 0.5° C higher in the channel than upstream, but dissolved oxygen in the channel was high, at 10.3 mg/L. In contrast, the upstream segment had 7.8 mg/L dissolved oxygen at nearly the same temperature. The difference is not surprising, however, given that the water depth in the channel was relatively low compared to the upstream segment, so aeration was much more likely. The downstream segment had a dissolved oxygen level comparable to upstream of the channel, at 6.6 mg/L. Consequently, all streams surpassed the state water quality criterion of 5 mg/L. Overall, water chemistry in Southwest Branch Site 10 does not appear to be a limiting factor for most biota.

Physical Habitat

The channel segment was degraded in terms of physical habitat. It received very low scores for velocity/depth diversity, channel alteration, riffle/run quality, and remoteness. It had no riparian vegetation, and human refuse was present in the stream. Moreover, there were no rootwads or woody debris to provide habitat for benthic macroinvertebrates. Nonetheless, this segment fared somewhat better than the upstream or downstream segments for some habitat parameters. For example, it had a slightly higher score for instream habitat and epifaunal substrate than the downstream segment, and it was estimated to be filled to 100% capacity, whereas the upstream and downstream segments were filled to 35% and 75%, respectively. All three segments were rated Good in terms of pool/glide/eddy quality.

Fish IBI Evaluation

Fish IBI scores for Southwest Branch Site 10 suggest that moderately good conditions exist. While the channel segment was rated Fair, its score of 3.75 is only slightly below those of the upstream and downstream segments, each rated Good at 4.00. The channel segment's score was comparatively low due to the lack of benthic (bottom-specialized) species and the high percentage (100%) of generalists. Nonetheless, it had an equally high fish density and biomass relative to the upstream and downstream segments, and had a high percentage (73%) of lithophilic spawners.

Predicted and Observed Fishes

Of the 24 species of fish predicted to inhabit the Southwest Branch Site 10 channel (Table 3), 12 species were found. Two additional species were also found that were not predicted. The primary reasons for species' absences were high ANC and high sulfate concentrations, both of which typically occur from the input of urban runoff. Similarly, the high percentage (29%) of impervious surfaces in the watershed were thought to have contributed to species' disappearance, since impervious surfaces deliver high amounts of runoff to streams and thereby increase the amount of runoff-associated contaminants. Impervious surfaces also inhibit fish survival and growth by increasing water temperatures, water velocities, and soil erosion.

Table 3: Expected species and potentially limiting habitat factors for Southwest Branch Site 10.

Species	Velocity/Depth	ANC ($\mu\text{eq/L}$)	Sulfate (mg/L)	Percent Impervious Surfaces
Eastern mudminnow				
Pirate perch		x	x	x
American eel			x	
Sea lamprey		x	x	x
Redfin pickerel		x	x	x
Common shiner	x			x
Tadpole madtom		x	x	x
Chain pickerel		x	x	x
Margined madtom		x		x
Spotfin shiner	x			x
Spottail shiner	x			x
Satinfin shiner				x

Barriers to Migration

The upstream, channel, and downstream segments had 11 species of fish in common, supporting the argument that the channel is not overly impaired relative to the upstream and downstream locations. Nonetheless, some species appeared to be localized. For example, the

anadromous sea lamprey (*Petromyzon marinus*) was found only upstream of the channel, and the eastern mudminnow (*Umbra pygmaea*) was found only downstream. Additionally, three species were collected in the channel and downstream (creek chubsucker (*Erimyzon oblongus*), golden shiner (*Notemigonus crysoleucas*), and yellow bullhead (*Ameiurus natalis*)). Four species were found upstream and downstream, but not in the channel (American eel (*Anguilla rostrata*), common shiner (*Luxilus cornutus*), satfin shiner (*Cyprinella analostana*), and bluegill (*Lepomis macrochirus*)). Consequently, the channel at this site is probably not acting as a barrier against the movement of fishes, but instead has limited the habitat available to some species.

Benthic IBI Evaluation

The benthic IBI scores indicated that the habitat quality at Southwest Branch Site 10 was more degraded than the fish IBI scores showed. In the channel, there was too small a total number of organisms (46) to generate an IBI score. The upstream and downstream segments were classified as Very Poor (1.86 and 1.30, respectively), having low species diversity and low total numbers of benthic organisms. At these two segments, the EPT (pollution-sensitive) taxa were represented by only one family, the Hydropsychidae (caddisflies), which are particularly pollution-tolerant and are typically found in urban streams. Additionally, the segments lacked specialized feeders. The segments' water quality, particularly regarding the high levels of sulfates and ANC, was thought to have played a more important role in low benthic species diversity than physical features.

Distribution of Herpetofauna

As was observed at other locations, herpetofauna were absent in the channel at Southwest Branch Site 10, due to a lack of suitable habitat. Herpetofauna were, however, found upstream and downstream from the channel. Upstream, the northern two-lined salamander (*Eurycea bislineata*) and the green frog (*Rana clamitans melanota*) were found. Downstream, green frog was found along with the pickerel frog (*Rana palustris*) and eastern box turtle (*Terrapene c. carolina*).

Southwest Branch of Western Branch, Site 17

Water Chemistry

Although both laboratory and field measurements of pH at Southwest Branch Site 17 showed

neutrality, the low level of ANC (131 $\mu\text{eq/L}$) indicated that some episodic acidification may occur during storms. However, DOC and nitrate-nitrogen were within natural ranges. Sulfates were higher at this location than any of the others, at 76 mg/L, and could reflect the presence of urban runoff.

Water temperature varied little across the length of the stream, ranging from 13.0 to 13.3° C. Dissolved oxygen was also consistent among the segments and was well above the state water quality criterion, ranging from 7.9 to 8.5 mg/L.

Physical Habitat

Nearly all habitat parameters indicated that the channel segment was significantly impaired relative to the upstream and downstream segments. For example, both the upstream and downstream segments were rated Good in terms of instream habitat and pool/glide/eddy quality, whereas the channel was rated Poor for these metrics. The channel segment also scored lowest for most other habitat parameters, such as remoteness, riffle/run quality, channel alteration, and riparian buffer width. No riparian vegetation was found along the channel. Additionally, the channel's substrate was unsuitable for bottom-dwelling biota, having 100% embeddedness, compared to the upstream substrate at 50% embeddedness or the downstream substrate at 35% embeddedness. Furthermore, the channel at Southwest Branch Site 17 was devoid of the woody debris and rootwads that provide habitat for benthic macroinvertebrates and fishes.

Fish IBI Evaluation

At Southwest Branch Site 17, the channel segment received the lowest possible score of 1.00. Only one individual of one species of fish (blacknose dace, *Rhinichthys atratulus*) was collected. Consequently, the segment scored poorly on every metric. The upstream segment did not score much higher, receiving a rating in the Poor category (2.25). The downstream segment was rated Good at 4.25. While the upstream segment had low biomass and was composed entirely of generalists, the downstream segment had high fish density and a significant portion of species that were specialized in some way (i.e., they were benthic species or lithophilic spawners). It also had a low percentage of pollution-tolerant species.

Predicted and Observed Fishes

At Southwest Branch Site 17, only one of the 21 predicted species was found (Table 4). Like most other channel segments, this segment had extremely low water depth, with a maximum depth of just 4 cm. There was also inadequate instream habitat, poor velocity/depth diversity, poor pool quality, and a high degree of channel alteration. All of these factors would need to improve in order to restore species to the channel.

Table 4: Expected species and potentially limiting habitat factors for Southwest Branch Site 17.

Species	Depth	Epifaunal Substrate	Instream Habitat	Velocity/ Depth	Pool Quality	Channel Alteration	Percent Impervious Surfaces
Creek chub	x		x	x	x	x	
Eastern mudminnow	x		x	x	x	x	
Tessellated darter	x		x	x	x	x	
Rosyside dace	x		x	x	x	x	
Pumpkinseed	x		x	x	x	x	
White sucker	x		x	x	x	x	
Fallfish	x		x	x	x	x	
Least brook lamprey	x	x	x	x	x	x	
Pirate perch	x		x	x	x	x	x
American eel	x		x	x	x	x	
Sea lamprey	x	x	x	x	x	x	
Redbreast sunfish	x		x	x	x	x	
Golden shiner	x		x	x	x	x	
Creek chubsucker	x		x	x	x	x	
Redfin pickerel	x		x	x	x	x	
Common shiner	x		x	x	x	x	
Tadpole madtom	x		x	x	x	x	x
Chain pickerel	x	x	x	x	x	x	

Margined madtom	x	x	x	x	x	x	
Bluespotted sunfish	x		x	x	x	x	

Barriers to Migration

No species was found upstream or in the channel that was not also found downstream. Blacknose dace (*Rhinichthys atratulus*) was found at all segments, and least brook lamprey (*Lampetra aepyptera*) and the catadromous American eel (*Anguilla rostrata*) were found both upstream and downstream. However, there were an additional 16 species of fish collected only at the downstream segment. Among these were the migratory sea lamprey (*Petromyzon marinus*) and juvenile largemouth bass (*Micropterus salmoides*). While it is possible the channel is acting as a barrier against the upstream movement of these species, the physical habitat and IBI scores seem to indicate that degradation of the upstream habitat may be the main factor preventing fish from occupying the area.

Benthic IBI Evaluation

Benthic IBI scores showed somewhat more disparity among the three segments at Southwest Branch Site 17 than they did at other locations. The upstream segment was rated the highest, at 3.29 (Fair), the downstream segment was intermediate, at 2.14 (Poor), and the channel segment was the most degraded, scoring 1.86 (Very Poor).

At all three segments, there were low total numbers of organisms and low species diversity. There was a predominance of organisms belonging to the family Chironomidae (midges). These organisms are well-known for their high pollution tolerance and are commonly found in impaired streams. Tubificid worms, also insensitive to pollution, were present at all three segments, whereas the intolerant EPT taxa were represented by only a few individuals upstream and downstream, and were non-existent in the channel.

Distribution of Herpetofauna

Herpetofauna observations indicate that the channel segment is unsuitable for some but not all species. The bullfrog (*Rana catesbeiana*) and northern two-lined salamander (*Eurycea*

bislineata) were found at both the upstream and downstream segments. Additionally, green frog (*Rana clamitans melanota*) was found at the upstream segment alone. However, a marbled salamander (*Ambystoma opacum*) was found at the channel segment, presumably using the channel as a corridor to better habitat upstream or downstream.

Recommendations

All concrete stream channels sampled in this study had inadequate habitat for many fish species and provided no suitable habitat for herpetofauna. Consequently, improving the physical characteristics of the channels and surrounding riparian zones would be the most worthwhile and effective means of stream restoration.

Structural alterations to the channels would enhance colonization by, and movement of, aquatic biota. One of the most helpful changes would be to create greater water depth and provide more space for fish and benthic macroinvertebrates to occupy. Additionally, since fish passage appears to be a problem at several segments, minimizing any ridges or drop-offs separating the channel from the upstream or downstream segments would be highly beneficial.

Another necessary modification would be to increase habitat heterogeneity, to provide the varied physical structure needed to enhance fish and benthic macroinvertebrate biodiversity. For example, allowing channel sediments to accumulate where there are none, and increasing the presence of stones, leaf litter, and woody debris would provide more spaces for animals to occupy as well as allochthonous food inputs.

To enhance instream habitat and to create a favorable environment for herpetofauna, changes could be made to the riparian areas surrounding the channel segments. Trees and other types of vegetation would provide cover for reptiles and amphibians, and would also contribute woody debris and allochthonous food sources to the stream. Additionally, water quality would probably improve as a result of riparian vegetation, since rooted soils tend to slow runoff from impervious surfaces, and the shade that trees create tends to keep stream water temperatures lower.

Unresolved factors affecting stream restoration

Some of the problems affecting the streams under investigation have resulted from widespread urbanization and will not likely be alleviated by localized channel restoration. Therefore, not all species of fishes expected to inhabit these stream sites will return after channel reconstruction. For example, sulfates were found to be relatively high at all sites, and as a byproduct of combustion, they will not be reduced by channel modification. Likewise, the large percentage of impervious surfaces in the four watersheds surrounding the channel segments affect physical habitat and water

quality in ways that cannot be locally controlled. However, further research may be necessary to determine exactly what land use processes exist in the watersheds draining all 12 segments, and how they may be affecting fish distributions.

Suggested priority sites for channel modification

Given the proposed modifications to the concrete channels, including increased water depth and habitat enhancement, the four sites were ranked based on the number of fish species expected to return following channel restoration. When determining the number of expected species, ambient water quality and land use conditions were considered.

Table 5 summarizes the fish communities expected to return to the four sites following channel improvement. The site that is capable of acquiring the largest number of species is Southwest Branch Site 17. It is followed in decreasing number of expected species reintroduction by Southwest Branch Site 9, Bald Hill Branch, and Southwest Branch Site 10, respectively.

Table 5. Type and number of fish species expected to return to each site following concrete channel improvement. Sites are listed from left to right in descending order of expected species reintroduction.

	SW17	BH2	SW9	SW10
Species expected to return to the channel segments	creek chub blacknose dace* tessellated darter rosyside dace pumpkinseed white sucker fallfish American eel redbreast sunfish common shiner swallowtail shiner	blacknose dace golden shiner eastern mudminnow pumpkinseed redbreast sunfish	blacknose dace tessellated darter pumpkinseed American eel white sucker	American eel
Species expected to return to the upstream segments	creek chub redbreast sunfish common shiner	redbreast sunfish creek chubsucker eastern mudminnow pumpkinseed	white sucker golden shiner	
Total species expected to be restored to channel and upstream segments	14	9	7	1

* one individual blacknose dace was collected in the cement channel. Numbers of blacknose dace are expected to be much higher in this stream following habitat improvements.

Literature Cited

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